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Particle Production and Energy Flow in W and Z Underlying Events

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PARTICLE PRODUCTION AND ENERGY FLOW IN W AND Z UNDERLYING EVENTS

CDF Collaboration*

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ABSTRACT

The properties of the hadrons produced in association to the production of W and Z have been measured using the CDF detector at Fermilab in p-$\bar{p}$ collisions at $\sqrt{s}$ = 1800 GeV.
The multiplicity, the transverse momentum, and the summed transverse energy spectra have been measured. The mean values of these quantities rise with increasing $p_t^{W/Z}$. The comparison with minimum bias events shows that when the $p_t^{W/Z}$ is small, the associated and the minimum bias events are very similar.

High invariant mass or high p_t particle production in high energy p-$\bar{p}$ interactions is accompained by an underlying structure of low p_t hadrons. The characteristics of these hadrons are determined by the color structure of the partons underlying the hard interacting partons [1,2]. The production of W and Z goes through the q-$\bar{q}$ annihilation by the Drell-Yan mechanism [3] as well as through radiative QCD processes. The Drell-Yan is a particularly clean process to study the underlying event since final states with purely leptonic boson decay can be selected. Comparing the characteristics of the underlying event structure with the tipical inelastic "soft" collisions, as are the so called minimum bias events, can provide information both on the hard parton interaction mechanism and on the soft interaction of the remaining partons. Some models are available which give predictions on the tranverse hadronic energy distribution in Drell-Yan processes, like the gluon resummation model [4-10]. Semi-quantitative comparison between the average multiplicities in the associated

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event and different processes can be obtained with the Dual Parton Model [11]. For example a crude application of this model, not taking into account the x values of the hard interacting partons, gives a ratio of the average multiplicity in the Drell-Yan event to minimum bias of 3/2. An upper limit on this ratio, of approximately 1.6 to 1.7, can be obtained on the base of geometric arguments and impact parameter considerations [12].

The results presented in this paper come from the analysis of the following processes: $W \rightarrow e\,\nu$, $W \rightarrow \mu\,\nu$, $Z \rightarrow e^+e^-$, and $Z \rightarrow \mu^+\mu^-$. The events were produced in p-$\bar{\rm p}$ interactions at $\sqrt{s}$ = 1800 GeV and were collected with the CDF detector at Fermilab during the 1988-1989 running period. They correspond to an integrated luminosity of 4.4 pb^{-1}.

The CDF detector is equipped with tracking systems in a solenoidal magnetic field, which provide track directions and momenta in the central region, and with a calorimeter system, segmented into towers in azimuth and pseudorapidity projectively oriented toward the interaction point, to measure the energy flow. A detailed description of the detector is reported elsewhere [13]. The W and Z production and properties have been carefully studied by the CDF Collaboration [14,15]. The selection criteria of the W/Z events with purely leptonic decays are exhaustively discussed in those pubblications. For the present analysis some additional cuts have been applied to further reduce the multiple vertex and the cosmic rays contamination. The selected samples contain 1406 $W \rightarrow e\,\nu$, 124 $Z \rightarrow e\,e$, 1170 $W \rightarrow \mu\,\nu$ and 109 $Z \rightarrow \mu\,\mu$.

The background in the above samples comes from misidentified W,Z leptonic decays and from QCD events. The total estimated background for the W sample is less than 10 %. The Z sample background is small and comes mostly from QCD events.

For comparison a sample of 26,000 minimum bias events have been analysed.

In the following preliminary results on multiplicity, tranverse momentum and $\sum Et$ distributions are presented in comparison with minimum bias events.

In fig.1a the multiplicity distributions of the charged particles associated to the weak boson are showed for the W and the Z samples. Also shown is the same distribution for the minimum bias sample. The multiplicity is measured in the pseudorapidity range $|\eta| \leq 3$ and for $p_t > 50$ MeV/c. The efficiency in this range is greater than 95 %. The data show a good agreement between W and Z events. The ratio of the mean charged multiplicity in the W/Z events to the same quantity in the minimum bias events is shown in fig. 2a as a function of the p_t of the W/Z. The ratio grows with $p_t^{W/Z}$. It is close to 1 for low $p_t^{W/Z}$ and goes to around 1.6 at higt $p_t^{W/Z}$. The behavior of this ratio in the small $p_t^{W/Z}$ region is not well explained on the base of the above mentioned models. Fig. 1b shows the p_t distribution of the associated charged particles in the W/Z events together with the same distribution for the minimum bias events. These spectra are measured in the η interval $|\eta| \leq 1$ and for $p_t > 400$ MeV/c. The average efficiency of the tracking system in this range is 99 %. The correction due to secondary interactions, particle decays, and photon conversion are less than 5 %. In fig. 2b the ratio of the mean p_t for W/Z events to the average p_t in minimum bias events is showed as a function of $p_t^{W/Z}$. This ratio rises, as expected, with increasing p_t of the boson.

The sum of the tranverse energy is measured in the calorimeter in the range of η between -3.6 to 3.6 as the sum of the Et measured in each calorimeter tower. Only towers with energy greater than 100 MeV have been taken into account. For the W/Z events the Et deposited in the calorimeter by the high energy lepton has been subtracted from the $\sum Et$. There are several uncertainties in the calorimeter response to low energy particles which have been taken into account. The typical correction factor in the total energy is about 1.4 [14,15]. The $\sum Et$ measure is affected by systematic errors related to the above mentioned uncertainties. Nevertheless many of the systematic effects tend to cancel when the ratio of the $\sum Et$ in the W/Z events to that in minimum bias events is considered. In fig. 1c the spectra of the $\sum Et$ for the W/Z events as well as for the minimum bias events are shown. The ratios of the mean values of the $\sum Et$ for W/Z events to the same quantity for the minimum bias, not shown in figure, is very close to 1 for $p_t < 5$ GeV/c and rise for increasing $p_t^{W/Z}$. From gluon resummation calculations higher values of this ratio are expected for low $p_t^{W/Z}$ [10,12].

In conclusion from these preliminary results on the particles produced in association with the production of intermediate bosons and from the comparison with minimum bias events the following configuration emerges.

- The properties of associated events in W and Z events are the same.
- The average values of the multiplicity, of the mean p_t, and of the total Et in events associated with W/Z production are higher than in minimum bias events due to the radiated gluon QCD jets balancing the p_t of the W/Z.
- The above mentioned mean values increase with increasing $p_t^{W/Z}$ as expected from gluon emission to balance the boson p_t.
- At low $p_t^{W/Z}$, below ≈ 5 GeV/c, the associated events are quite similar to minimum bias. The p_t of the W is measured using the calorimeter. This measure has large uncertainties. Smearing effects and correction on the $p_t(W)$ are still under study. However from QCD calculations, using the gluon resummation model, higher values for the associated events with respect to minimum bias are expected also at low $p_t^{W/Z}$.

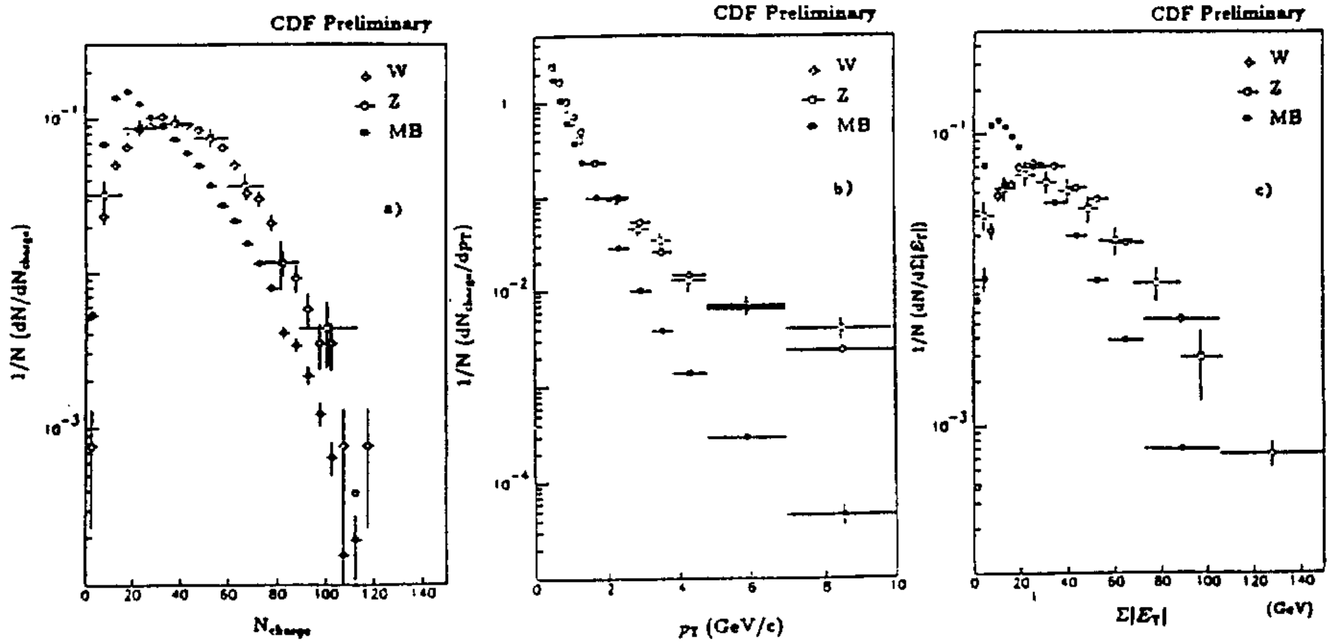

Figure .1: a) Charged multiplicity distributions for W and Z associated particles and for minimum bias events. The multiplicity is calculated in the eta range $|\eta| \leq 3$ and for $p_t > 50$ MeV/c. b) Transverse momentum distributions for W and Z associated particles and for minimum bias events. The transverse momentum is measured in the $|\eta| \leq 1$ and for $p_t > 400$ MeV/c. c) $\sum Et$ distributions for the W and Z associated particles and for minimum bias events. The $\sum Et$ is the sum of the transverse energy deposited in the calorimeter towers with η between -3.6 and 3.6.

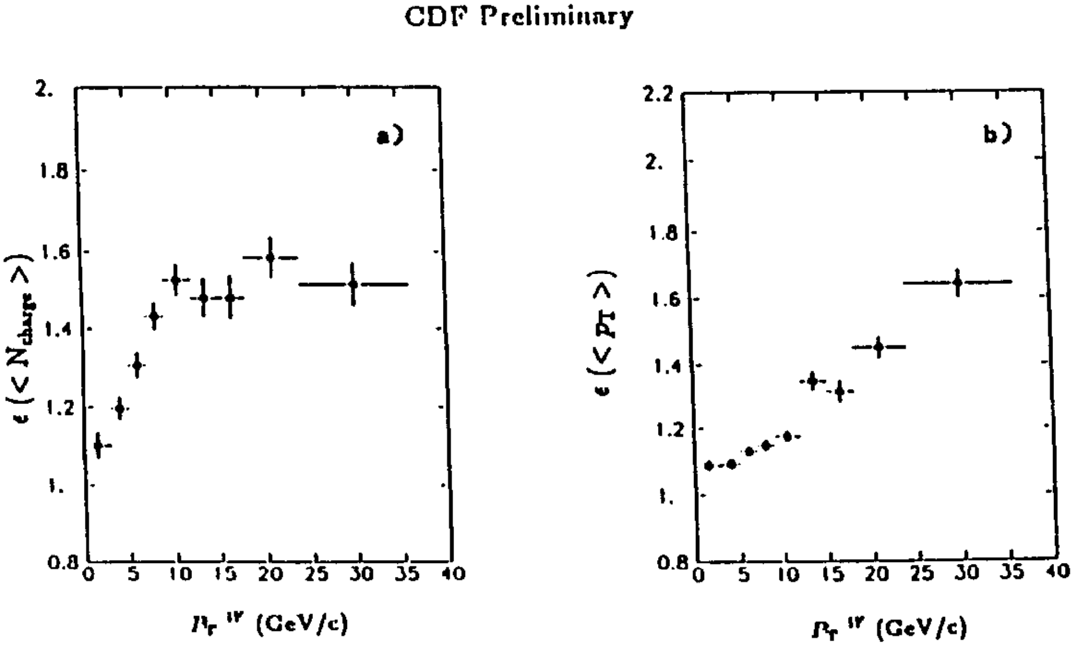

Figure .2: a) $\epsilon(\langle N_{charge} \rangle)$, the ratio of the mean charged multiplicity of the W/Z associated particles over the same quantity for the minimum bias events, as a function of the $p_t^{W/Z}$. b) $\epsilon(\langle p_t \rangle)$, the ratio of the mean transverse momentum of the W/Z associated particle over the same quantity for the minimum bias events, as a function of the $p_t^{W/Z}$. No correction for smearing effects have been applied to the $p_t^{W/Z}$.

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